ECE322L -Homework 3 (100 points)
Assigned on Thursday, 02/13/2020-11 am
Due on Thursday, 02/20/2020-11 am

The transistor parameters of the NMOS in the figure below are $V_{TN} = 0.4$ V, $k = 100$ μA/V^2, and $\lambda = 0$.

(a) Determine R_D such that $V_{DSQ} = V_{DS(sat)} + 0.25$ V.

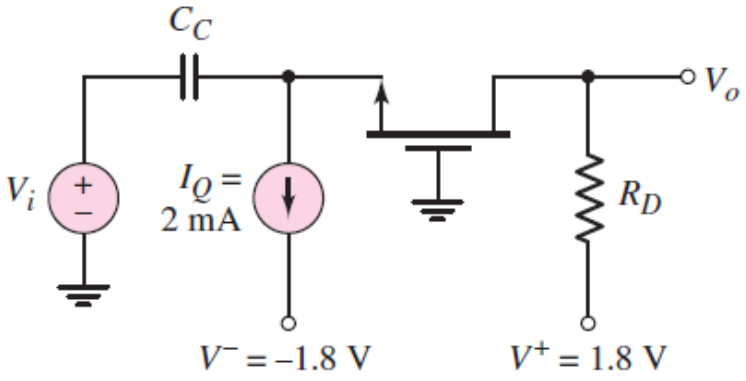
(b) Determine the transistor W/L ratio such that the total small-signal voltage gain is $Av = 6$ V/V.

(c) What is the value of V_{GSQ}?

(d) What are the input and the output resistance of the amplifier?

(e) Please, comment on the performance of the circuit below as a voltage amplifier.

In solving the problem, you should use the MOSFET equations provided in the Neamen book. Assume a midband frequency for the input signal.



(a) $V_O = (V_{DS}(sat) + 0.25) - V_{GS}$

$V_O = V_{GS} - V_{TN} + 0.25 - V_{GS} = -0.4 + 0.25 = -0.15\,\text{V}$

$$R_D = \frac{1.8 - (-0.15)}{2} = 0.975\,\text{k}\Omega$$

(b) $A_v = g_m R_D$

$6 = g_m(0.975) \Rightarrow g_m = 6.154\,\text{mA/V}$

$$g_m = 2\sqrt{\left(\frac{k_n'}{2}\right)\left(\frac{W}{L}\right)I_{DQ}}$$

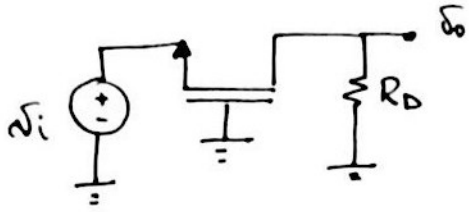
$$6.154 = 2\sqrt{\left(\frac{0.1}{2}\right)\left(\frac{W}{L}\right)(2)} \Rightarrow \left(\frac{W}{L}\right) = 94.7$$

(c) $$I_{DQ} = \left(\frac{k_n'}{2}\right)\left(\frac{W}{L}\right)(V_{GSQ} - V_{TN})^2$$

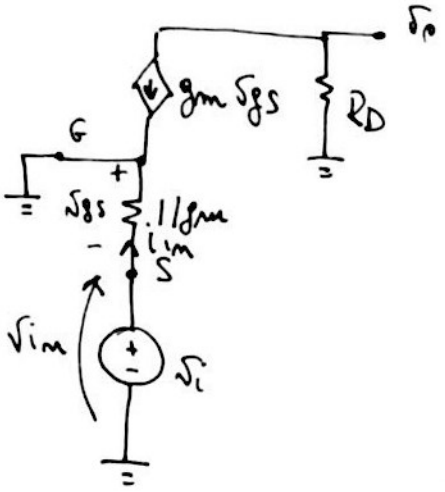
$$2 = \left(\frac{0.1}{2}\right)(94.7)(V_{GSQ} - 0.4)^2 \Rightarrow V_{GSQ} = 1.05\,\text{V}$$

d)

ac circuit



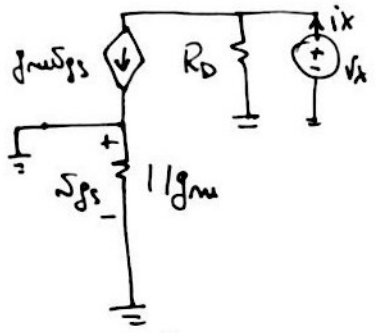
Small-signal equivalent circuit



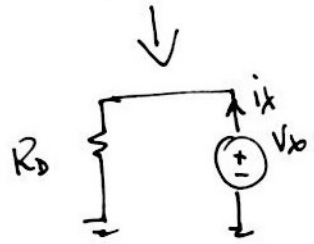
$$R_{in} = \frac{v_{in}}{i_{in}}$$

$$v_{in} = (1/g_m)\, i_{in}$$

$$R_{in} = \frac{1}{g_m} = \frac{1}{6.154\,m} = 162\,\Omega$$



$$R_{out} = \frac{v_x}{i_x}$$



$$R_{out} = R_D = 0.975\,k\Omega$$

e) The circuit has a positive gain, which is also larger than 1 V/V. This is a desired attribute for a voltage amplifier. The small input resistance and the moderate output resistance limit the circuit performance as a voltage amplifier as they don't allow an efficient transfer of the signal to the input port of the amplifier and of the output signal to a load, respectively.